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A COMPREHENSIVE EVALUATION OF WEAR BEHAVIOUR OF ALUMINIUM MATRIX COMPOSITES WITH VARIOUS METALLIC AND NON-METALLIC PARTICULATES AS REINFORCEMENT

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ABSTRACT

Wear, which is one of the most important characteristic leads to a costly damage in machine parts, unless it is reduced. All the engineering components are naturally imply with wear. The composites with inclusion of various types of particulate reinforcements of both metallic and non-metallic in Aluminium base metals or alloys are denoted as Aluminium Metal Matrix Composites or simply called as AMMCs. These have tremendous attributes that they can be tailor made with respect to their achievable properties according to the required applications in wide and variety range of applications. Most of the applications in mechanical, industrial, automobile, aerospace and naval are associated with wear properties where dry sliding occurs. In the current paper, a comprehensive attempt was made for attaining overview about the connection among the wear parameter like rate of wear, coefficient of friction and, wear volume loss which are the dependants of the factors like type, size and volume of particulates, load, rate of sliding, time of sliding, and sliding distance with respect to various types of AMMCs. A highlighted attempt was made for the compilation of various compositions of AMMCs and the probable methods of manufacturing along with input and output parameters.

KEY WORDS: Aluminium Metal Matrix Composites (AMMCs), Reinforcements, Dry-Sliding & Wear Parameters

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Original Article

INTRODUCTION

'Wear' is the property that acts on both ends positive and negative when considered in engineering applications. For anecdotal reasons the wear property intentionally induced or reduced depending on the application. Wear may be because of corrosion, adhesion, and abrasion. Each of these has their own advantages and disadvantages that lead to benefits and troubles depending on the type of application for a particular purpose. The benefits or problems may be influenced by the factors type of material, type of lubrication and amount of surface finish. Among Metal Matrix Composites (MMCs), Aluminium Matrix Composites (AMCs) hold more than 69% by weight for industrial functions as they holds excellent mechanical and thermal properties couples with better tribological properties [1-2]. Under dry lubrication conditions, the Aluminium based matrix composites are exhibiting poor wear resistance. These are confined to very limited applications due to this inadequacy [2-3]. It is examined that the strength of matrix alloy AA7075 was enhanced by 6%, on addition of hybrid particulate (SiC+ Al_2O_3) [4]. Among the hybrid reinforcement particulates RHA (Rice Husk Ash), Al_2O_3 and graphite in AA6063, the graphite influenced more on the wear rate. As graphite composition increases from 0% to 1.5% the rate of decreases drastically, as the graphite particulates are soft in nature [5]. The AMMCs with inclusion of hard metallic or

ceramic particulates are greatly influenced by wear mechanisms like abrasive and adhesive [6, 7, 8]. In the global scenario, due to increasing competition for manufacturability with reduced weight to strength ratio regarding engine parts of automobiles, the research in the AMMCs area is still running after new and innovative techniques for better performance [9]. The need is still in take away situation and the lacunae are to be bridged for the emerging applications and needs in all the related industries.

Influence of Volume and Size of Reinforcement Particulates on Wear Behaviour of Ammcs

The wear properties of AMMCs are greatly influenced type of reinforcement particulates and volume and size of the particulate as well. Depending on the type of application and requirement of level of attainment of particular outcome from the material the type of reinforcement and its level of composition may be tailored. In the case of Al6061 matrix the hybrid composite is examined with inclusion of Silica and alumina particulates and the rate of wear was substantially decreased with gradual increase of volume of content of reinforcement particulate due to formation of high hard phases [10]. In another case of Al7075, the wear property of the composite was greatly influenced by the size of the Al_2O_3 particulate which was used as the inclusive powder particulate and found the optimized parameters at 200 microns size of particulate [4].

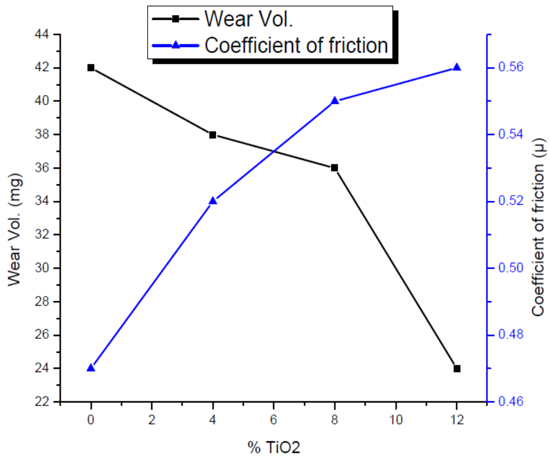

Figure 1: Effect of % TiO_2 Content on Wear Properties.

The rate of wear resistance is better for the hybridized composite compared to ordinary composite which is considered as the base matrix. Further, the figure 1 reveals that, the volume content of the reinforcement particulate is greatly influencing the wear properties. The coefficient of friction is increasing with the percentage of particulate in hybrid composite, whereas, the wear rate is decreasing. The higher values of permanent strain (plastic strain) due to TiO_2 particulate which is adhesive in nature leads to higher values of frictional coefficient [13]. The distribution fashion as well as the volume and size of the reinforcement particulates are the determinants of stirring speed, impeller size, and holding temperature. These process variables in turn, are prime cause for the attainment of the required mechanical properties [11].

EFFECT OF STIR CASTING PARAMETERS

Stirring Speed

The figure 2 shows the schematic representation of effect of stirring speed on the shape of the surface of the matrix melt, in which, the line C represents the surface of matrix melt before starting of stirring. When a rapid stirring starts, then the surface rise unto line A. The line B represents the shape of the surface after stirring process ends and this is slightly above

the line C due to the inert gas drawn into the melt by the vortex formed by the stirring process [11].

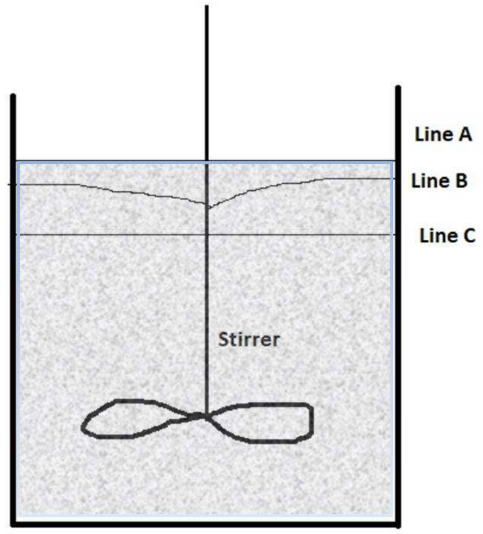

Figure 2: Effect of Stirring Speed on Vortex Formation.

Stirring Time and stirring Speed

Depending on the type of matrix and its properties like viscosity and wettability and chemical composition and the type of reinforcement material the stirring speed and stirring time vary instant to instant. These parameters govern the vortex which results in required richness of mixing of matrix and reinforcements. We may also use the optimization techniques like ANOVA and Artificial neural networks for a better combination of stirring parameters to obtain the required output properties for the prepared composite. Using the ANOVA technique, it is concluded that at 550 rpm stirring speed and 12% weight percentage of $SiC+Al_2O_3$ particulate in AA7075 matrix will result in optimal or better strength properties [4].

Wear Behaviour - Rate of Wear, Coefficient of Friction (Output Parameters) with Respect to Load, Speed, Sliding Distance and Time of Sliding (Input Parameters)

Among industrial, automobile, aviation, and shipping, the wear property plays a prime role in the selection and design of suitable materials. The selected material should withstand for long and processes a high strength to weight ratio where AMMCs come in front of the screen. During the investigation of wear properties for aluminium matrix based hybrid composite reinforced with silicon carbide and copper, the weight percentage of reinforcement particulates plays predominant role to influence the wear rate of the composite. While the other parameters load and sliding velocity stood in the next two positions respectively to affect the rate of wear of the composite [12]. The composite prepared with garnet particulate (Gr (p)) as reinforcement in ZA27 was compared for wear rate with base alloy and the results were shown in figure 3. The rate of wear for matrix or base alloy is uniform till 200N, later suddenly raised above the load 200N. But, for the composites the transition load point is higher than that of 200N as there is no sudden raise in rate of wear is observed. It is also saying that the increase in percentage of particulate proportion improved the rate of wear [17].

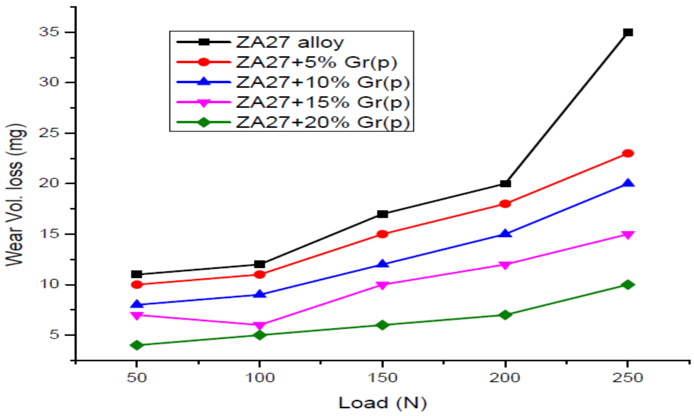

Figure 3: Load vs. Wear vol. Loss (mg).

The figure 4 illustrating the effect of applied load on the wear parameter coefficient of friction. As the load increases, the coefficient of friction is gradually increasing for all types of compositions. But, at higher load the coefficient of friction difference is limited as the adhesion phenomenon between the particles of composite and the surface taking place. Improved hardness is the main reason for enhancement of wear resistance with the inclusion of TiC particles, which was illustrated in the figure 5 for various percentage compositions of TiO_2 [15].

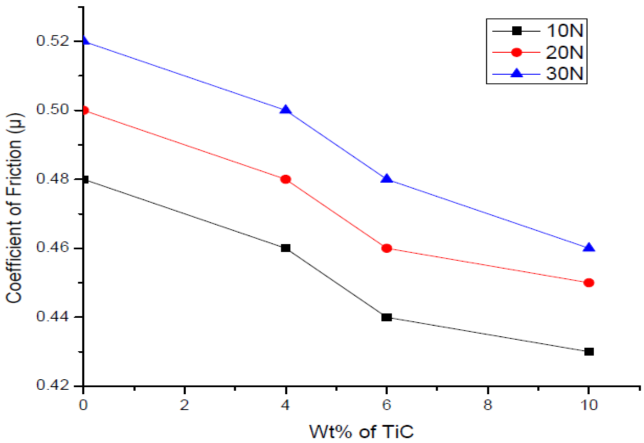

Figure 4: Wt% of TiC vs. COF.

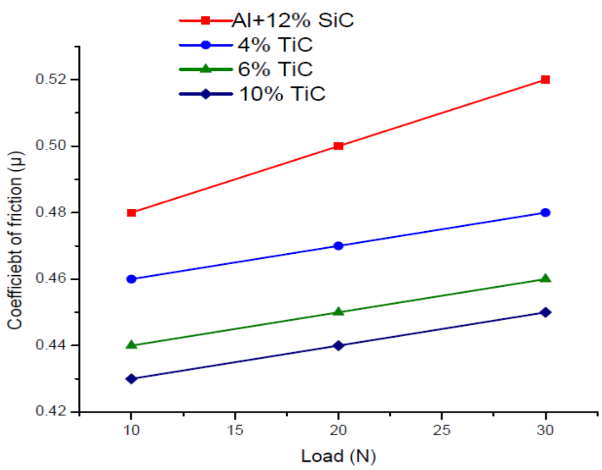

Figure 5: Load vs. COF.

The figure 6 shows the improvement of volume of wear of the material with load particularly for composite and this is because of the heat generated between the sliding surface and composites surface as heat softens materials which in turn causes easy aberration of material surface [16]. Figure 7 explain the effect of sliding speed on the wear parameter wear volume loss. When speed increases, volume loss also increases from the compositions. At higher speeds, degenerated heat leads to soften the bond between the matrix and reinforcement which is the cause for higher laws of where volume at higher speeds sliding [17].

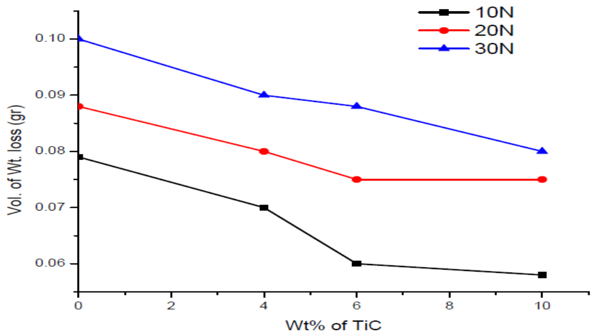

Figure 6: Wt% of TiC vs. Wear Vol. Loss.

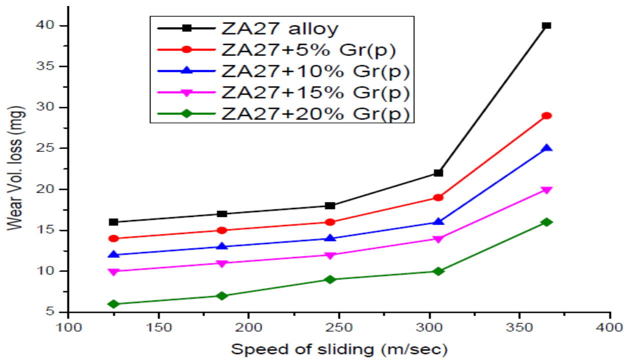

Figure 7: Sliding Speed vs. Wear Vol. Loss.

Figure 8 explains the effect of sliding distance on the parameter of rate of wear. At lower sliding distances, the rate of wear is higher. At the beginning of sliding, the surface gruffness is having higher sharpness for both pin and disc which results in temperature rise which leads to adhesion welding open material with disc and hence increase in rate of wear. But as the sliding distance further increases the effluent debris which is formed due to the wear of pin which causes skidding of pin in the air track and hence decrease in the rate of wear [16].

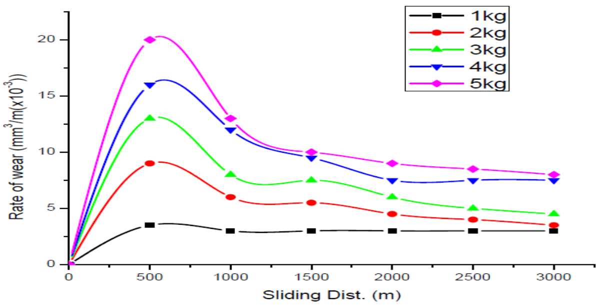

Figure 8: Sliding Dist. Vs. Rate of Wear.

Comparison of Composition or Type of Reinforcement Particulates and Method of Manufacturing

Overview of input and output parameters along with the manufacturing methods of composites with inclusion of various types of reinforcements was given in table 1.

Table 1: A Comparative Study of Parameters and Methods for Various Compositions of Reinforcements

Matrix Material	Type of Reinforcement	Compositions	Method of Manufacturing	Input Parameters for Wear Test	Output Parameters	Ref. No.
AA7075	SiC	2%, 4%, 6%	Stir casting	Stirring speed, Processing Temperature	Hardness, Strength	[4]
	Al_2O_3	2%, 4%, 6%				
AA6063	Alumina	0%, 0.5%, 1%, 1.5%	Stir casting	Composition	Rate of wear	[5]
	Rice husk Ash					
	Graphite					
Al+15%SiC	TiO_2(Rutile)	0%	Powder Metallurgy Technique	Sliding Velocity, Distance, Load	Wear resistance, Frictional coefficient	[13]
		4%				
		8%				
		12%				
LM30	Sillimanite (Al_2SiO_5)	3%	Stir casting	Load and Distance of Sliding	Rate of Wear	[16]
		6%				
		9%				
		12%				
		15%				
		18%				
LM25	Activated carbon	10%	Stir casting	Time of sliding (sec)	Volume of wear(mg)	[14]
	Activated carbon + Mica (Hybrid)	20%				
Al+12%Si	TiC	4%	Melting Process	Load(N), Distance(m), % Reinforcement	Rate of Wear, Coefficient of Friction	[15]
	TiC	6%				
	TiC	10%				

CONCLUSIONS

- The investigations shown that the hybrid composites are for more ahead of wear properties compared to mono composites.
- The wear mechanism greatly affected by the hardness of the particulate reinforcements.
- As the volume percentage of particulate reinforcements increases, the rate of wear increases.
- In some type of reinforcements like ceramic particulate, wear properties like wear volume loss and rate of wear may decrease after some extent of sliding length as the heat produces between surfaces which are rubbing.
- Sliding speed is proportional to the rate of wear regarding many the composites with soft inclusions.
- The load is always proportional to the rate of wear volume loss.

FUTURE SCOPE

- For the hybrid composites with high strength alloy particulate are having so much of scope for studying the wear properties.

REFERENCES

1. J.U. Prakash, S.Ananth, G.S. kumar, T.V.Moorthy. Multi-objective optimization of wear parameters for aluminium matrix composites (413/B_4C) using grey relational analysis. Materials Today, 2018; 5: 7207–7216.
2. S. Mohan Kumar, R. Pramod, H K Govindaraju. Evaluation of mechanical and wear properties of aluminium AA430 reinforced with SiC and MgO. Materials Today, 2017; 4: 509–518.
3. Ikumapayi, OMOLAYO M., and ESTHER T. Akinlabi. "A comparative assessment of tensile strength and corrosion protection in friction stir processed AA7075-T651 matrix composites using fly ashes nanoparticles as reinforcement inhibitors in 3.5% NaCl." Int J Mech Prod Eng Res Develeopment 9 (2019): 839-54.
4. M K Surappa. Aluminium matrix composites: Challenges and opportunities. Sadhana, 2003; 28(1 & 2): 319-334.
5. B. Rajeswari, K.S. Amirthagadeswaran, K.G. Anbarasu. Investigation on mechanical properties of aluminium 7075-silicon carbide-alumina hybrid composite using Taguchi method. Australian Journal of Mechanical Engineering, 2015; 13: 127-135.
6. K. K. Alaneme, K. O. Sanusi. Microstructural characteristics, mechanical and wear behaviour of aluminium matrix hybrid composites reinforced with alumina, rice husk ash and graphite. Engineering Science and Technology an International Journal, 2015; 1-7.
7. Shivam, Aparmit, Amit Singla, and Amit Chauhan. "Wear analysis by Taguchi technique of Al6061 based hybrid composite reinforced with SiC and Al2O3." International Journal of Mechanical and Production Engineering Research and Development 7.4 (2017): 371-380.
8. M. Walczak, D. Pieniak, M. Zwierzchowski. The tribological characteristics of SiC particle reinforced aluminium composites. Archives of Civil and Mechanical Engineering,2014; 226: 1-8.
9. Stuart M. Lee. ASM Handbook of Composite Reinforcements. WILEY-VCH, 1992; p. 354.
10. S.T.Mavhungu, E.T.Akinlabi, M.A.Ontiri, F.M.Varachiya. Metal Matrix composites for Industrial use: Advances and trends. Procedia Manufacturing, 2016; 7: 178 – 182.
11. Varuzan M. Kevorkijan. Aluminum Composites for Automotive Applications: A Global Perspective. Aluminum Fabrication, 1999; p.3.
12. Singh, Gyanendra, AJITANSHU VEDRTNAM, and HIMANSHU BHATI. "Fabrication and Charecterisation of Aluminum-Graphite Composite Material." International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) 7.4 (2017): 313-320.
13. E. Bahmani, V. Abouei, Y. Shajari, S. H. Razavb, O. Bayat. Investigation on Microstructure, Wear Behavior and Microhardness of Al−Si/SiC Nanocomposite, Surface Engineering and Applied Electrochemistry, 2018; 54(4): 350-354.
14. J. Hashim, L. Looney, M.S.J. Hashmi. Metal matrix composites: production by the stir casting method. Journal of Materials Processing Technology, 1999; 92: 1-7.
15. Mohammed, Karrar Ibrahim, and Younus Mohammed Younus. "Experimental investigation into the effect of erosion and corrosion in pipes conveying fluid on its frequencies." International Journal of Energy and Environment 10.1 (2019): 25-32.
16. Ajitanshu Vedrtnam, Anuj Kumar. Fabrication and wear characterization of silicon carbide and copper reinforced aluminium matrix compos. Materials Discovery, 2017; 9: 16–22.
17. Viswakarma, P. R. A. D. Y. U. M. N. A., S. A. N. J. A. Y. Soni, and P. M. Mishra. "An Effect of Reinforcement and Heat Treatment On Aa7075 Metal Matrix Composite–A Review." International Journal of Mechanical and Production Engineering

Research and Development 8.6 (2018): 275-288.

18. *C. Antony vasantha Kumar, J. Selvin Rajadurai. Influence of rutile (TiO_2) content on wear and microhardness characteristics of aluminium-based hybrid composites synthesized by powder metallurgy Trans. Nonferrous Met. Soc, 2016; 26: 63−73.*
19. *RAO, Pothamsetty Kasi V., et al. "Experimental Investigation of Thermal stability of carbon nanotubes reinforced Aluminium matrix using TGA-DSC Analysis." International Journal of Mechanical and Production Engineering Research and Development 8.3 (2018): 161-168.*
20. *B.N.Sarada, P.L. Srinivasa Murthy, G. Ugrasen. Hardness and wear characteristics of metal matrix composites produced by stir casting technique. Materials Today: Proceedings, 2015; 2:2878 – 2885.*
21. *Belete S. Yigezu, P. K. Jha, M. M. Mahapatra. Effect of Sliding Distance, Applied Load, and Weight Percentage of Reinforcement on the Abrasive Wear Properties of In Situ Synthesized Al–12% Si/TiC Composites. Tribology Transactions, 2013; 56-4: 546-554.*
22. *Sandeep Sharma, T. Nanda, O.Pandey. Effect of particle size on dry sliding wear behaviour of sillimanite reinforced aluminium matrix composites. Ceramics International, 2017; 0272- 8842.*
23. *Jitendra M. Mistry, Piyush P. Gohil. Experimental investigations on wear and friction behaviour of Si_3N_4p reinforced heat treated aluminium matrix composites produced using electromagnetic stir casting process. Composites Part B, 2019; 18: 1-5.*

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